DISCOVERY

Toxicity of seed oils of neem (*Azadirachta indica*) and desert date (*Balanites aegyptiaca*) on the development of tropical warehouse moth (*Ephestia cautella*) in maize (*Zea mays*)

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ABSTRACT

One major constraint to sustainable production and availability of maize is its susceptibility to infestation by insect pests both in the field and during storage of the grains and its products. Therefore, this study was carried out to assess the biotoxic effect of neem (*Azadirachta indica*) and desert date (*Balanites aegyptiaca*) seed oils against the developmental stages of the tropical warehouse moth (*Ephestia cautella*) and Dichlorvos (standard product). The bioassay was conducted in the laboratory under ambient temperature and relative humidity of 21 -39°C and 55-75%, respectively. Maize grains (100 g) were treated with four different concentrations (10, 15, 20 and 25 ml/l) of neem and desert date seed oils, respectively and Dichlorvos at the rate of 10 ml/l as standard control. The experiment was laid in a Completely Randomized Design (CRD) with three replications. Data obtained were analyzed using analysis of variance (ANOVA) and significantly different means were separated using New Duncan Multiple Range Test (NDMRT) at 5% probability level. The results showed that, the neem, desert date oils and Dichlorvos significantly ($p < 0.05$) caused mortality of adults of *E. cautella*. More so, it was observed that Dichlorvos, neem and desert date oils significantly ($p < 0.05$) suppressed oviposition rate, development of eggs and immature stages and the emergence of *E. cautella* from maize grains. Fewer eggs; 25 - 61 and 21 – 41, were laid on grains treated with neem and desert date oils, respectively against the control which had 184 eggs. Therefore, neem and desert date oils can be used as substitute to synthetic insecticides because of its ability to protect maize grain from *E. cautella* infestation.

Keywords: Dichlorvos, *Azadirachta indica*, maize, *Balanites aegyptiaca*, *Ephestia cautella*

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1. INTRODUCTION

Maize (*Zea mays*) storage is constrained by a number of factors which include attack from pathogens and insect pests. Insect pests are the major threat destroying approximately 20-50% of stored maize in most African countries (CABI, 2012). In Sub-Saharan Africa, food grain losses during storage at farm level can reach as high as 25-40% (Mondal and Chakraborty, 2016). Plant-derived insecticides have always been a major weapon in the farmers' armory in managing insect pests of their farm produce (Okrikata, 2021). It has been an ancient practice to mix neem (*Azadirachta indica*) materials in stored product against insect pests in countries where neem is much (Okrikata, 2021). Neem has been shown to have reasonable insecticidal properties; hence its extracts have been employed as botanicals in a more environmentally friendly and safe means against insect pest control which are largely less expensive than synthetic insecticides (Okrikata and Oruonye, 2013).

Neem products have proved to be as potent as many commercially available synthetic pesticides (Shehu et al., 2010). In Ghana for example, cocoa beans mixed with neem leaves solution remained free from attack by *Ephestia cautella* up to 9 months in storage (Saxena, 2006). Furthermore, mesocarp of fruit extracts of *B. aegyptica* has been reported to possess mosquito larvicidal activity against *Aedes aegypti, Anopheles arabiensis, Culex quinquefasciatus* and *Culex pipiens* (Chothani and Vaghasiya, 2011). A Study on Khapra beetle revealed that seed oil of *B. aegyptica* achieved high larval mortality of the beetle which exerted a repellent effect on the pest larvae and reduced stored sorghum damage by 30% within 45 days (Elamin and Satti, 2013). It was also reported that, cowpea seeds treated with *B. aegyptica* oil (10ml/50 g), resulted to 100 % mortality at 48 hours after infestation (Nwaogu et al., 2013).

A better understanding of biopesticide mode of action may further help to raise their profile among the public and policy makers to enable realize their potential in sustainable food production (Kumar and Singh, 2015; Okrikata, 2021). In view of this, more research is required to determine the efficacy of plant materials on a wide range of storage insect pests, hence, in this study; we evaluated the toxicity of seed oils of *A. indica* and *B. aegyptica* on the development of *E. cautella* in stored maize grains.

2. MATERIALS AND METHODS

Experimental Site

The experiment was conducted in the Entomology Laboratory of the Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University, Yola, Adamawa State, Nigeria. Yola is located in the north eastern part of Nigeria on geographical coordinates of latitude and longitude 9°12′0″N and 12°28′59.99″E, respectively; while the laboratory is located on latitude 9°20″49'N and longitude 12°29"44'E (Google compass, 2022). The experiment was carried out at room temperature and relative humidity range of 21-35°C and 45–75 %, respectively in 2022.

Experimental Materials

Dichlorvos was purchased from an agrochemical merchant in Yola ultra-modern market, Adamawa State while, Neem seed oil and Desert date oil were prepared by method described by Akinjide, (2019). The steps involved in extracting neem and desert date oils is as follows: Picking and selection of ripe fruits, depulping of fruit, decortications of seeds, winnowing, sun drying seeds, roasting of seeds, grinding of seeds into paste using grinding machine, stirring of paste in a pot placed on fire with addition of little hot water at intervals, collection of oil and pressing of dough on grinding stone to squeeze out the remaining oil.

Rearing of *Ephestia cautella*

Parent stock of tropical warehouse moth (*E. cautella*) were obtained from laboratory cultures in the Department of Crop Protection and reared on poultry mash (wheat bran + honey + glycerine + yeast) and placed in a glass jar (FAO, 2022). The poultry mash and glass jars used for raising the culture were initially sterilized at 60°C for 3 hours so as to kill any insect or pathogen in the grains (Allotey and Azaleclor, 2000). Thirty (30) unsexed adult *E. cautella* were picked using aspirator and introduced into the mash in each glass jar. The glass jars were then covered with muslin cloth held with rubber band to aid ventilation and to prevent escape of insects from the jars. The glass jars were kept on trays smeared with oil so as to prevent insects and mites from crawling into the cultures. Adult *E. cautella* were picked out four days after oviposition. The emerging F_1 adults of 2-3 days old were used for the bioassay (Shehu et al., 2010).

Bioassay of mortality of *E. cautella* on treated maize grains

The neem and desert date seed oils were applied as a mixture in which the oils were dissolved in water with liquid soap as emulsifier (Adarkwah et al., 2008; Shehu et al., 2010). Four different concentrations of neem and desert date oils (10, 15, 20 and 25 ml/l) each were formed, Dichlorvos at 10 ml/l was used as positive control. To evaluate contact toxicity of neem and desert date oils,

four different concentrations of the oils (10, 15, 20 and 25 ml/l) and Dichlorvos (10 ml/l) were applied to 100 g of maize grains in the glass jars, shaken for 5 minutes for uniform distribution of the oils and Dichlorvos on the grain surface. There was also an untreated/negative control (0 ml/l) set up. Ten (10) adults (2-3 days old) of *E. cautella* were transferred to each jar. Each treatment was replicated three times in a completely randomized design. Mortality was counted after 24, 48, 72 and 96 hours.

Tests for oviposition of *E. cautella* on treated maize grains

One hundred grams (100 g) of maize were treated with four different concentrations of neem and desert date oils (10, 15, 20 and 25 ml/l) and Dichlorvos (10 ml/l) and a negative control (0 ml/l) and each treatment was replicated three times. Twenty (20) adult *E. cautella* of 2-3 days old of mixed sexes were introduced into the jars containing the treated grains, arranged in a completely randomized design on a laboratory bench. Adult insects were removed after 3 days oviposition period. The eggs laid were sieved and counted with the aid of hand lens.

Effects of Neem and Desert Date Seed Oils on Immature Stages of *E. cautella*

Effects on eggs of E. cautella

To determine the toxicity effect of the seed oils on *E. cautella* eggs, twenty adult *E. cautella* were used to infest 100 g of maize grains in glass jars. Parent adults were removed after 3 days of infestation/egg laying. The infested grains were then treated with four different concentrations of neem and desert date oils (10, 15, 20 and 25 ml/l) each and Dichlorvos (10 ml/l). There was also an untreated set up (0 ml/l) which served as negative control. The treatment was replicated three times in a completely randomized design. The emerged adults of *E. cautella* were counted and recorded as number of young adults F_1 per 100 g of maize (Adarkwa et al., 2008; Boateng and Kusi, 2008).

Effect on larvae of E. cautella

One hundred grams (1000 g) of maize grain and grits were treated with four different concentrations of neem and desert date oils as above and replicated three times in a completely randomized design (CRD). Twenty larvae *E. cautella* of 3-5 days old were used to infest the maize grains. The jars were covered with white muslin cloth held with rubber bands. Adult *E. cautella* that emerged from the treatments were counted and recorded (Boateng and Kusi, 2008).

Effect on pupae of E. cautella

Twenty (20) larvae of *E. cautella* were transferred into petri dish containing poultry mash and allowed to pupate. Ten (10) pupae were carefully removed and placed into another petri dish. The pupae in each petri dish were treated with four different concentrations of neem and desert date oils (10, 15, 20 and 25 ml/l) each and Dichlorvos (10 ml/l) using micro applicator. The negative control (0 ml/l) was treated with water only. The treatments were replicated three times and arranged in a completely randomized design. The emerging adults were counted and recorded as described by Adarkwah et al., (2008) and Shehu et al., (2010).

Data Analysis

Data obtained were subjected to Analysis of Variance (ANOVA) suitable for Completely Randomized Design using SAS software, 9.4 version (SAS institute, Cary, NC, USA). Significantly different means were separated using New Duncan Multiple Range Test (NDMRT) at $p < 0.05$.

3. RESULTS

Contact Toxicity of Neern and Desert Date Oils to *E. cautella* on Treated Surfaces

Results for contact toxicity of neem and desert date oils to *E. cautella* on treated surfaces (Table 1). After 24 hours, the highest percent mean mortality (53.33%) caused to *E. cautella* was recorded on grains treated with Dichlorvos while the lowest (0.00%) was recorded on lowest concentration (10 ml/l) of neem and Desert date oils and also the untreated/negative control. There was significant difference ($p < 0.05$) between the percent mean mortality caused to *E. cautella* by Dichlorvos (53.33%) and the oils (0.00-23.33%). The difference was not significant among the percent mean mortality caused by different concentrations of the oils. There was also no significant difference between the percent mean mortality caused by different concentrations of the oils (0.00-23.33%) and the untreated control (0.00 %). After 48 hours, mortality increased in all treatments. There was no significant difference ($p < 0.05$) between the mortality caused by lowest concentrations (10 ml/l) of the oils and the negative control but the difference was

significant between Dichlorvos (63.33 %) and different concentrations of the oils (3.33-40.00%). After 72 hours, there was significant difference ($p < 0.05$) between the percent mean mortality caused by all the treatments (13.33-100%) and the untreated control (0.00%). There was also a significant difference ($p < 0.05$) between the percent mean mortality caused by Dichlorvos (100%) and the oils (13.33-40.00%) but the difference was not significant between Dichlorvos (100%) and the highest concentration (25 ml/l) of neem oil (93.33%). After 96 hours, highest concentration (25 ml/l) of neem and desert date oils caused mortality of 100 and 60% to *E. cautella*, respectively.

The overall best performance was recorded on Dichlorvos (10 ml/l) and is significantly different from the two oils which were at par with neem oil at 25 ml/l (100.00%). Desert date oil concentrations (15, 20 and 25 ml/l) performed well as it influenced 46.67–60.00% mortality. There was no significant difference ($p > 0.05$) between the different levels of the neem and desert date oils.

Table 1 Percentage Mean Mortality of *E. cautella* on Treated Maize Grains

Treatment	Percent (%) mean mortality with time (hrs)			
	24 hrs	48 hrs	72 hrs	96 hrs
Control (0.00 ml/l)	0.00^{b}	0.00^{e}	0.00^{e}	0.00^{d}
Neem oil				
10.00 ml/l	0.00^{b}	13.33^{cde}	20.00^{cd}	43.33^{bc}
15.00 ml/l	16.67^{b}	26.67^{bc}	40.00^{b}	63.33^{b}
20.00 ml/l	3.33^{b}	3.33^{de}	13.33^{de}	40.00^{c}
25.00 ml/l	23.33^{b}	40.00^{b}	93.33^{a}	100.00^{a}
Desert date oil				
10.00 ml/l	0.00^{b}	3.33^{e}	26.67^{bcd}	46.67^{bc}
15.00 ml/l	10.00^{b}	23.33^{bcd}	36.67^{bc}	56.67^{bc}
20.00 ml/l	10.00^{b}	26.67^{bc}	30.00^{bcd}	60.00^{bc}
25.00 ml/l	10.00^{b}	23.33^{bcd}	36.67^{bc}	60.00^{bc}
Dichlorvos (10.00 ml/l)	53.33^{a}	63.33^{a}	100.00^{a}	100.00^{a}
CV (%)	10.90	15.39	13.47	20.26
p value	0.0016	<0.0001	<0.0001	<0.0001

Means in same column with the same alphabet(s) as superscripts are not significantly different at p = 0.05 using New Duncan Multiple Range Test for mean separation

CV = Coefficient of Variation

Effect of Neem, Desert Date Oils and Dichlorvos on Oviposition of *E. cautella*

The number of eggs laid by *E. cautella* on the maize grains treated with different concentrations of neem, desert date oil and Dichlorvos (Figure 1). Eggs laid decreased with increase in concentration of the oils. The highest mean numbers of eggs (184.67) were laid in the control and the lowest (12) were laid on grains treated with Dichlorvos. There was significant difference ($p < 0.05$) between the eggs laid on the treated grains (12-61.33) and the control (184.67) but there was no significant difference between the different concentrations of neem (24.67-61.33) and desert date oils (21-41). The difference was also not significant between the different concentration of desert date oil (21-41) and Dichlorvos (12), so also between Dichlorvos and neem oil at concentrations of 20 and 25 ml/l (24.67-38.33). The overall best performance was recorded on Dichlorvos (10 ml/l) fallowed by desert date oil (25 ml/l), then neem (25 ml/l) but the difference between them was not significant.

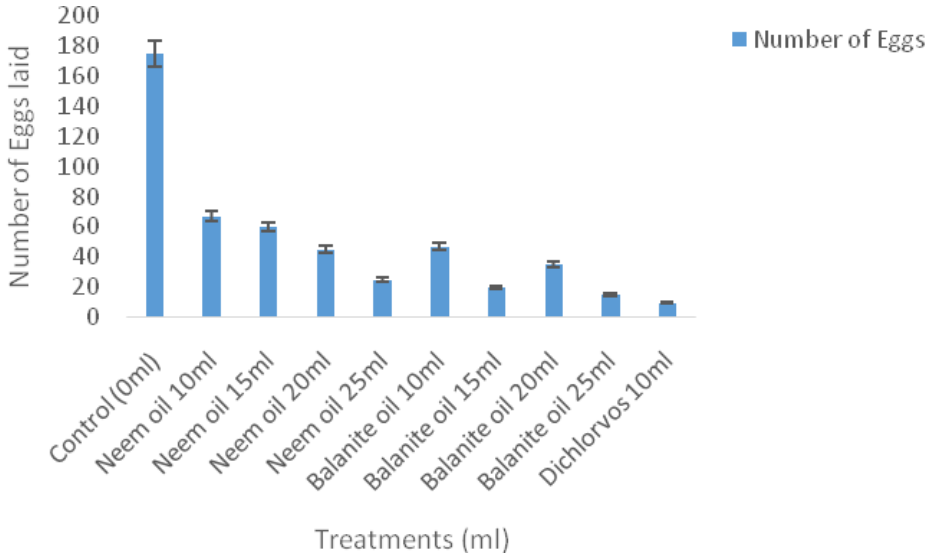

Figure 1 Effects of Neem, Desert Date Oils and Dichlorvos on Oviposition of *E. cautella*

Effect of Neem, Desert Date Oils and Dichlorvoson Immature Stages of *E. cautella*

Effect on eggs of E. cautella

The mean number of *Ephestia cautella* progeny that emerged on grain treated with different concentrations of neem, desert date oil and Dichlorvos (Table 2). Progeny emergence decreased with increase in concentration of the oils. The highest mean number of progeny emergence (26.67) was recorded on the control. There was complete inhibition of progeny emergence on grains treated with higher concentrations of neem and desert date oils (20 and 25 ml/l) and Dichlorvos. There was significant ($P \leq 0.05$) difference between the progeny emergence on the treated grain samples (0.00-5.00) and the control (26.67) but there was no significant difference among the different concentrations of neem and desert date oils (0.00-4.55) except the lowest concentration (10 ml/l) of neem oil (5.00). The difference was also not significant between the mean number of progeny emergence on grain samples treated with Dichlorvos (0.00) and different concentrations of the oils (0.00-4.55) except the lowest concentration (10 ml/l) of neem oil (5.00). Dichlorvos (10 ml/l), desert date oil (20 ml/l) and neem oil (20 ml/l) performed equally with no emerged progenies.

Effect on larvae of E. cautella

Table 2 showed the number of progeny that emerged when *Ephestia cautella* larvae were used to infest grain treated with different concentrations of neem, desert date oil and Dichlorvos. Neem and desert date oils reduced the emergence of *E. cautella* adults when grains containing larvae were treated with different concentrations of the oils (Table 2). The highest mean number of progeny emergence (76.67%) was recorded on the control/untreated grains. There was complete inhibition (0.00%) of progeny emergence on grains treated with neem (25 ml/l), desert date oils (20 and 25 ml/l) and Dichlorvos. There was significant difference ($p < 0.05$) between the treatments (0.00-26.67%) and the control (76.67%) but no significant difference between the corresponding concentrations of neem and desert date oils (0.00-26.67%, each). Some of the adult *E. cautella* that emerged were deformed. Dichlorvos (10 ml/l), desert date oil (20 and 25 ml/l) and neem oil (25 ml/l) performed equally with no emerged progenies.

Effect on pupae of E. cautella

The mean number of progeny that emerged when *E. cautella* pupae were treated with different concentrations of neem, desert date oil and Dichlorvos (Table 2). Neem and desert date oils reduced the emergence of *E. cautella* adults when the pupae of were treated with different concentration of neem and desert date seed oils compared to the untreated grain. The highest mean number of progeny emergence (93.33%) was recorded on the control and the lowest number (20.00%) was recorded on grains treated with neem oil (25 ml/l). There was significant difference ($p < 0.05$) between the treatments (20.00-43.33%) and the control (93.33%) but there was no significant difference among the different concentrations of the oils (20.00-43.33%) and Dichlorvos (23.33%) on the pupae and subsequent emergence of *E. cautella* adults. There was also no significant difference among the different concentrations of neem (20.00-43.33%) and also among the different concentrations of desert date oil (30.00-40.00% emergence). Some of the adult *E. cautella* that emerged were deformed. The overall best performance was recorded on neem (25 ml/l) treated grains, followed by Dichlorvos (10 ml/l) and then desert date oil (20 and 25 ml/l) but the difference among them was not significant.

Table 2 Percentage Mean Mortality of Immature Stages of *E. cautella* Treated with Neem, Desert Date Oil and Dichlorvos

Treatment	Mean number of progeny emergence (%)		
	Eggs	Larva	Pupa
Control (0.00 ml/l)	26.67[a]	76.67[a]	93.33[a]
Neem oil			
10.00 ml/l	5.00[b]	26.67[b]	36.67[bc]
15.00 ml/l	0.67[c]	26.67[b]	36.67[bc]
20.00 ml/l	0.00[c]	3.33[c]	33.33[bc]
25.00 ml/l	0.00[c]	0.00[c]	20.00[c]
Desert date oil			
10.00 ml/l	4.33[bc]	26.67[b]	40.00[bc]
15.00 ml/l	1.00[c]	20.00[b]	43.33[b]
20.00 ml/l	0.00[c]	0.00[c]	30.00[bc]
25.00 ml/l	0.00[c]	0.00[c]	30.00[bc]
Dichlorvos (10.00 ml/l)	0.00[c]	0.00[c]	23.33[c]
CV (%)	22.26	13.64	19.49
p value	<0.0001	<0.0001	<0.0001

Means in same column with the same alphabet(s) as superscripts are not significantly different at p = 0.05 using New Duncan Multiple Range Test for mean separation
CV = Coefficient of Variation

4. DISCUSSION

Mortality of Neem and Desert Date Seed Oils on *E. cautella*

Contact toxicity of neem, desert date oils and Dichlorvos

Contact toxicity of neem and desert date seed oils to *E. cautella* on treated grains caused substantial mortality to adult of *E. cautella* with neem oil at 25ml/l corresponding with Dichlorvos (10 ml/l) after 96 hours of exposure. This finding corroborates the discovery of Adarkwa et al., (2008) which showed that when Whitman's filter paper was impregnated with neem oil (Calneem) at concentration of 3.0%, > 50 % mortality of *Tribolium castaneum* was recorded after 72 hours of treatment. It is also in consonant with the report of Mokhtar et al., (2021) which showed that *B. aegyptiaca* seed extract caused 100% mortality on *T. castaneum* at 1.13 mg/cm^2 after 12 – 24 hours. That plant-based materials can induce mortality of storage pest, *E. cautella*, in particular, was shown by Akinneye and Ogungbite, (2013) who revealed that applying powder of *Eugenia aromatic* at 2g/20g on Cocoa bean could cause 100% mortality of the adult insect.

Effect of A. indica and B. aegyptiaca Seed oils on Oviposition of E. cautella

Seed oil of neem was effective in reducing the number of eggs laid by *E. cautella* and this was largely dose dependent. Such finding was reported by Agboka et al., (2009) who showed that neem oil caused significant effects on oviposition of moth (*Mussidiani grivenella*) in dose dependent manner. Similarly, Bhatnagar et al., (2001) reported that cowpea seeds treated with neem oil significantly reduce oviposition of cowpea bruchids. The desert date oil and Dichlorvos were found to be equally effective on *E. cautella.* The difference was not significant between the different concentration of desert date oil and DDVP and so also between DDVP and neem oil at concentration of 20-25 ml/l. This is in harmony with the findings of Shehu et al., (2010) which showed no significant difference in the efficacy of neem seed oil and Pirimiphos-methyl (Actellic) in suppressing the oviposition of *E. cautella.* Lale and Mustapha, (2000) also found no significant difference in the efficacy of neem seed oil and pirimiphos-methyl (Actellic) in reducing oviposition of *C. maculatus.* It therefore suffices to say that same applies to *E. cautella* despite they are not from the same order with C. *maculatus.* Nwaogu et al., (2013) reported that, very few eggs were laid in *B. aegyptiaca* oil treated cowpeas with a mean fecundity of 9 to 12 eggs on *B. aegyptiaca* treated cowpea when compared with control which had a mean fecundity ranging from 46 to 52 eggs per female. This is a clear indication that *B. aegyptiaca* and *A. indica* oils have anti-oviposition effects and can be used to reduce oviposition of *E. cautella.*

Effect of Neem, Desert date oils and Dichlorvos on Immature Stages of *E. cautella*

Toxicity to eggs of E. cautella

The number of *E. cautella* progeny that emerged when maize grains containing eggs were treated with different concentrations of neem, desert date oil and Dichlorvos revealed that progeny emergence decreased with increase in concentration of the oils. This agrees with a report by Da-Silva et al., (2013) which showed that the toxicity of neem oil to eggs of *Diatraea saccharalis* varied with the dose and the age of the eggs and that of Shehu et al., (2010) which indicated that neem oil (Calneem) inhibited the development of eggs of *E. cautella.* Agboka et al., (2009) also reported that neem oil caused significant ovicidal effects on eggs of moth (*Mussidiani grivenella*) in a dose dependent manner. Similarly, the study by Akinneye et al., (2019) revealed that *Eugenia aromatica* oil at the rates of 0.5, 1.0, 1.5, 2.0 and 2.5 ml all completely inhibited egg hatching and adult emergence of *E. cautella.* Neem oil has been considered to have an ovicidal action as its active constituents may obstruct the egg membrane and hinder the embryo's respiratory exchanges (Da-Silva et al., 2013). Our study showed complete inhibition of progeny emergence from grain samples treated with neem and desert date oils (20 and 25 ml/l) and Dichlorvos corroborating the report of Shehu et al., (2010) which showed that at a concentration of 7 ml/l, neem oil caused complete inhibition of the development of eggs of *E. cautella* to adult stage. Nwaogu et al., (2013) reported that more than 50 % of the total eggs laid by cowpea bruchids in treated samples treated with desert date oils died at various stages of development. Similar essential oils have also shown some ovicidal effects. It was reported that essential oils of eucalyptus, rosemary and lemon grass at concentrations of 15 ml/l inhibited eggs of *E. cautella* from hatching by 89.3, 53.5 and 60.7%, respectively (Al-Taie and Sabr, 2018). Similarly, Akinneye et al., (2019) reported that contact toxicity of ethanolic extract of *E. aromatic* oil at concentrations of 5 ml/l completely inhibited egg hatch and adult emergence of *E. cautella*.

Toxicity to larva of E. cautella

Neem and desert date oils reduced the emergence of *E. cautella* adults when grains containing larvae were treated with different concentrations of the oils. At concentration of 20-25 ml/l, we observed that the two oils used caused complete inhibition of the development of *E. cautella* larvae to adult stage corroborating the report by Shehu et al., (2010) which showed that at concentration of 7 ml/l, neem oil caused complete inhibition of the development of larvae of *E. cautella* to adult stage. Our observation also agrees with that of Eziah et al., (2011) which indicated that 5 ml/l and 6 ml/l of neem oil induced larval mortality of *E. cautella* at a range of 47.5 to 55.0% after 96 hours of exposure. It was reported that essential oils of lemon grass, rosemary and eucalyptus at concentrations of 15 ml/l caused mortality to larvae of *E. cautella* by 60, 40 and 16%, respectively after 72 hours of exposure (Akinneye and Ogungbite, 20l3). Similarly, Sunarti, (2003) reported that application of neem oil to cocoa beans deterred larval *E. cautella* feeding by 92%. We also observed that some of the emerged adults of *E. cautella* were deformed as a result of the oil treatments as reported by Shehu et al., (2010).

Inhibition of the development of immature stages of the insect species by the neem oil in the present study could be due to the presence of decalin, hydroxyl furan, nimbin and solannin fragments of azadiractin. Decalin is reported to have growth regulation and development effect while hydroxyl furan fragment induces antifeedant effect (Schmutterer, 1990). Inhibition of the development of immature stages of the insect species by *B. aegyptiaca* oil in the present study could be due to the presence of Saponins. Chothani and Vaghasiya, (2011) reported that extracts from several parts of *B. aegyptiaca* were shown to exhibit insecticidal activities against variety of pests and steroidal saponin is believed to be the main causative agent. Saponin extracts from *B. aegyptica* kernel was found to have high larvicidal effects on mosquitoes (Chapagain et al., 2008). Neem oil has a multi-pronged effect, being effective on larval or nymphal stages of insects (Obeng-Ofori, 2008). Similarly, Akinneye et al., (2019) reported that contact toxicity of *E. aromatic* oil at concentrations of 15, 20 and 25% caused mortality of larvae of *E. cautella* by 37.33, 62.67 and 74.67%, respectively after 72 hours of exposure. The reduction in development of immature stages of the insect used in the present study increased the protectant potential of *A. indica* and *B. aegyptiaca* seed oils against insect damage during storage.

Toxicity to pupae of E. cautella

Neem and desert date oils reduced the emergence of *E. cautella* adults when pupae of *E. cautella* were treated with different concentration of neem and desert date oils compared to the untreated grain. Shehu et al., (2010) also reported that at concentration of 7 ml/l, neem oil reduced the development of pupae of *E. cautella* to adult stage. Some of the emerged adults look deformed. Boulahbel et al., (2015) reported that neem oil delays reproduction in pests as it causes lethal toxicity during the pupal stage leading to various morphological deformations such as malformed adults, partial ecdysis and molt blocking that defers and inhibits adult formation. Schneider et al., (2017) further reported that in the treatment of young pupae with higher concentrations of neem, some

adults were unable to completely get rid of the exuvia, with some regions of the body remaining with parts of the old cuticle (pupa), such as wings, legs or abdomen. Our observation corroborates these aforestated findings.

5. CONCLUSION

Neem and Desert date oils were found to be effective against *E. cautella* infestation on maize grains. We observed that neem and desert date oils contain insecticidal, anti-ovipositant and ovicidal properties. Contact toxicity of the oils on treated surfaces at concentration of 10 - 25 ml/l caused 100 % mortality to larvae of *E. cautella* after 72 hours. A complete inhibition of egg development (l00%) by the oils (20 and 25 ml/l) and pupae development was induced and some of the adults *E. cautella* that emerged from the eggs, larvae and the pupae treated with lower concentrations of the oils were deformed.

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Informed consent

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Ethical approval

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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